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(54) Title: ABSORBENT STRUCTURE WITH FLUID-IMPERMEABLE PATCH

(57) Abstract

This invention relates to an absorbent structure, preferably containing superabsorbent polymer in an absorbent layer, and in particular, to a structure with a centrally located fluid-impermeable patch which redirects an insulting fluid around it in a manner to increase the overall containment efficiency of the structure. The absorbent structure of this invention is suitable for use in various absorbent articles and absorbent devices, such as, for example, disposable diapers, sanitary napkins, incontinent devices and garments, and training garments. The invention also relates to methods to determine the location of moisture within an absorbent structure and to study fluid flow and absorption of aqueous fluid by absorbent structures in real time.

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ABSORBENT STRUCTURE WITH FLUID-IMPERMEABLE PATCH

This invention relates to an absorbent structure, preferably containing superabsorbent polymer, and in particular, to a structure with diversionary means at the central insult site which redirects the insulting fluid in a manner to increase the overall containment efficiency of the structure. The invention also relates to methods to determine the location of moisture within an absorbent structure and to study fluid flow and absorption of aqueous fluid by an absorbent structure in real time.

Absorbent structures are used in absorbent devices for personal use, such as diapers, sanitary napkins, incontinent devices and garments, training pants, and in other applications, such as surgical or medicinal absorbent pads or drapes, bed pads and cable shielding. The incorporation of superabsorbent polymers in an absorbent structure greatly increases the absorbing power of the structure.

However, depending upon the device or garment in which the structure is used and the nature of the insult to which the structure is subjected, little of the absorbing power of the superabsorbent polymers in the structure may be effectively utilized. When there is a localized insult wherein the insulting fluid impinges upon a relatively small area of the absorbent structure at a rapid rate, such as, for example, when a baby urinates in a diaper, the insulted area of the structure may be initially overwhelmed. Thus, a basic problem requiring a solution in the field of absorbent structure design is the rapid absorption of a localized insult and distribution of the insulting fluid through the structure so that it can be effectively absorbed by the superabsorbent polymer.

U. S. Patent No. 4,880,419 discusses the problems of distribution and containment of the superabsorbent polymer within the absorbent structure, and the problems of gel blocking and lack of wicking of the polymer itself. The patent discloses an absorbent article which has discrete superabsorbent containing layers and wicking means which is wound about and between the superabsorbent containing layers.

U. S. Patent No. 4,973,325 discusses fluid handling problems encountered in the use of several absorbent structure containing devices and discloses an absorbent article containing a pair of absorbents positioned adjacent to each other. The article has a coaxially aligned transfer member for facilitating movement of body fluid from the cover downward and outward to distant areas of absorbent.

U. S. Patent No. 5,151,091 discusses fluid handling problems that may result from the greater longitudinal dimension of various personal absorbent products. The patent discloses an absorbent product having means to direct the fluid flow substantially along the longitudinal direction of the product and substantially limit transverse flow which can result in side failures.

U. S. Patent No. 4,778,459 discloses a disposable diaper which contains an expanse of impermeable material including a channel for guiding urine to an island of absorbent material.

U. S. Patent No. 3,927,673 discloses an absorbent article for diapers which has a water impervious interlayer sheet with a plurality of small holes therethrough disposed between the top sheet and the absorbent pad.

U. S. Patent No. 3,934,588 discloses a disposable diaper structure with facing layers having areas of preferential flow made by variations in the thickness of the material.

U. S. Patent No. 4,699,619 discloses an absorbent structure which employs cellulosic layers of differing density and pore size to control fluid flow by wicking.

The prior art has recognized the problems of directing the flow of the insulting fluid away from the immediate insult site to structural areas of high absorbency, and various designs have been proposed with structural elements to accomplish this end. However, most of the actual measurements made on absorbent devices report only the overall characteristics of the device. Few attempts have been made to correlate actual functional workings of a device with the theoretical design of the absorbent structure.

U.S. Patent No.'s 4,699,619 and 5,176,668 disclose methods by which it was attempted to verify that the structural elements of the device actually work in the way they were designed to work by measuring the distribution of fluid in the structure after insult. This was done by cutting, weighing, drying and weighing again various sections of the structure to determine fluid distribution.

It would be advantageous to have available a more effective absorbent structure for use in absorbent articles which has means for distribution of fluid insults and more efficient absorption thereof. Further, it would be useful to have an analytical method for observing fluid distribution within the structure, especially a rapid method allowing real time observation of fluid flow.

In one embodiment the invention relates to an absorbent structure comprising:

(A) an absorbent layer having dimensions of length, width and thickness, the absorbent layer having at least an upper surface with dimensions of length and width, wherein the ratio of length to thickness is from 1 to 1000 and the ratio of width to thickness is from 1 to 500; and

(B) a fluid-impermeable patch centrally located adjacent to or covering a part of the upper surface of the absorbent layer, the area of the patch being from 2 to 90 percent of the area of the upper surface of the absorbent layer.

In another embodiment the invention relates to an absorbent structure comprising:

(A) an absorbent layer having dimensions of length, width and thickness, the absorbent layer having at least an upper surface with dimensions of length and width, wherein the ratio of length to thickness is from 1 to 1000 and the ratio of width to thickness is from 1 to 500;

(B) a fluid-permeable layer adjacent to the upper surface of the absorbent layer; and

(C) a fluid-impermeable patch centrally located on a part of at least one surface of the fluid-permeable layer, the area of the patch being from 2 to 90 percent of the area of the upper surface of the absorbent layer.

The absorbent structure of this invention is suitable for use in various absorbent articles and absorbent devices, such as, for example, disposable diapers, sanitary napkins, incontinent devices and garments, and training garments. Depending upon the requirements of the device or garment in which the absorbent structure is used, the absorbent structure may be produced in a wide variety of sizes and shapes. For the most effective use of the absorbent structure of this invention, the absorbent structure should be positioned in the device or garment in which it is used with the fluid-impermeable patch between the absorbent layer and the anticipated source of the fluid insult for which the device or garment is designed.

In another embodiment this invention relates to a method for determining the location of aqueous fluid within an absorbent structure with the use of magnetic resonance imaging comprising the steps of:

(A) performing a magnetic resonance imaging scan on the absorbent structure;

(B) collecting and storing data from the magnetic resonance imaging scan;

(C) visually displaying the data.

Magnetic resonance imaging (MRI) is used in the analytical method of this invention to study the location of aqueous fluids absorbed in absorbent structures in three dimensional space without mechanically impacting the structures. Because of the rapidity of the method, fluid flow can be observed in real time, and the effects of multiple fluid insults upon an absorbent structure can be observed sequentially.

FIG. 1 is a schematic of the experimental layout.

FIG. 2 is a view showing the scanning protocols used for MRI scanning of absorbent structures.

FIG. 3A is a contour plot of a coronal scan.

FIG. 3B is a surface plot B of a coronal scan.

FIG. 4 is a graphic illustration of data for total signal versus volume of insulting fluid.

FIG. 5A is a screen image from an MRI scan of a transverse slice of an absorbent structure.

FIG. 5B is a surface plot corresponding to FIG. 5A.

FIG. 5C is a profile of the maxima of moisture content corresponding to FIG. 5A and FIG. 5B.

FIG. 6A is a series of profile plots showing fluid movement over time for a first fluid insult.

FIG. 6B is a series of profile plots showing fluid movement over time for a second fluid insult.

FIG. 6C is a series of profile plots showing fluid movement over time for a third fluid insult.

FIG. 7A is a surface plot for the first fluid insults to an absorbent structure.

FIG. 7B is a surface plot for the second successive fluid insult to an absorbent structure.

FIG. 7C is a surface plot for the third successive fluid insult to an absorbent structure.

FIG. 8A is a side view of contour lines of various relative moisture contents in an absorbent structure without a fluid-impermeable patch after a first fluid insult as measured by MRI.

FIG. 8B is a side view of contour lines of various relative moisture contents in an absorbent structure without a fluid-impermeable patch after a second fluid insult as measured by MRI.

FIG. 8C is a side view of contour lines of various relative moisture contents in an absorbent structure without a fluid-impermeable patch after a third fluid insult as measured by MRI.

FIG. 8D is a side view of contour lines of various relative moisture contents in an absorbent structure with a fluid-impermeable patch after a first fluid insult as measured by MRI.

FIG. 8E is a side view of contour lines of various relative moisture contents in an absorbent structure with a fluid-impermeable patch after a second fluid insult as measured by MRI.

FIG. 8F is a side view of contour lines of various relative moisture contents in an absorbent structure with a fluid-impermeable patch after a third fluid insult as measured by MRI.

The absorbent structure comprises an absorbent layer whose primary function is to absorb fluid insults to the structure. The absorbent layer desirably is composed of fluff or a blend of fluff and superabsorbent polymer. The fluff may generally be one or more of a number of fibrous, fiber-containing or non-fibrous materials which are themselves high in fluid absorption capacity. Desirable materials for fluff include, for example, cotton lintels and comminuted wood pulp. A preferred type of fluff is comminuted wood pulp.

Alternatively, the absorbent layer may be composed primarily of or consist essentially of superabsorbent polymer. In this embodiment, superabsorbent polymer is present in one or more alternative forms including woven or nonwoven fibers, fabric, particles, powder or a sheet.

In a combination of fluff with superabsorbent polymer, the fluff functions to provide containment means for the superabsorbent polymer particles. The fluff also functions to provide rapid initial absorption of fluid insults with subsequent transport of the fluid to the superabsorbent polymer. The superabsorbent polymer may be in the form of a powder or small particles, fibers, film or a combination thereof. Where the absorbent layer is composed primarily of superabsorbent polymer in various forms, the functions discussed above for fluff can be performed by one or more of the various superabsorbent polymer forms.

Desirably, the absorbent layer of an absorbent structure contains at least 0.1 gram of superabsorbent polymer, preferably at least 1 gram and more preferably 3 grams or more of superabsorbent polymer. While a high superabsorbent polymer content is primarily a matter of cost, desirably the absorbent layer of an absorbent structure contains less than 1 kg, preferably less than 100 grams and more preferably 15 grams or less of superabsorbent polymer.

The fluff used may be a blend of fluff with modified cellulose, other cellulosic materials, or other synthetic materials. Desirable materials include meltblown synthetic fibers and meltblown synthetic fibers containing fluff. Particularly desirable are combinations with superabsorbent polymer. Desirable synthetic materials include, for example, polyethylene, polypropylene, polyesters, polyamides, copolymers of polyesters and polyamides and bicomponent fibers. Modified cellulose fibers include those produced to have high wet stiffness.

Alternative forms for the absorbent layer include a laminate consisting of an absorbent film with cellulose tissue on one or both sides. Other desirable forms include an open cell foam, an open cell foam in combination with fluff and/or superabsorbent polymer. Cellulose of synthetic fiber tissue may be wrapped or woven around or within the absorbent layer. The layer may be of varying density, thickness and composition to control liquid holding capacity and liquid distribution.

A wide variety of superabsorbent polymers may be used in the absorbent layer, such as, for example, those disclosed and described in U.S. Patent No.'s 5,075,344; 5,064,582; 5,045,614; 4,861,849; 4,833,222; 4,833,198; 4,708,997; 4,666,983; 4,734,478; 4,857,610; 4,605,401; 5,145,906; 5,322,896; 4,541,871; 4,808,637; 4,812,486; RE 32,649; 4,286,082; 5,280,079; 5,280,078; 5,281,673; 5,281,683; 5,241,009; 5,284,936; 5,286,827; 5,281,683; 5,124,188; 5,002,986; 5,102,597 and 4,043,952.

The overall dimensions of the absorbent structure of this invention can vary greatly, depending upon the materials of construction and the particular use for which the

structure is intended. Usually, the absorbent layer has basically the same length and width as the overall absorbent structure. In alternative embodiments, the absorbent layer may have an upper surface area which is from 35 to 99 percent of the area of the absorbent structure.

When incorporated into some common absorbent devices, such as, for example, disposable diapers, incontinent devices or garments and training pants, the length of the absorbent layer desirably is from 5 cm to 100 cm, preferably from 10 cm to 75 cm, and more preferably from 20 cm to 50 cm. The width desirably is from 2 cm to 30 cm, preferably from 4 cm to 20, and more preferably from 7 cm to 15 cm. The thickness of the absorbent layer desirably is from 0.1 cm to 5 cm, preferably from .15 cm to 2.5 cm, and more preferably from 0.2 cm to 1.2 cm.

The fluid-permeable layer is permeable to insulting fluid liquids, primarily aqueous liquids, having dissolved or suspended therein a wide variety of inorganic and organic materials. Among the more challenging fluid insults are those of biological origin, such as, for example, urine and blood. Preferred materials for the fluid-permeable layer include, for example, airlaid or meltblown synthetic fibers, which may be bonded or partially bonded thermally or, for example, with latex adhesive. Synthetic polymeric materials for use in the fluid-permeable layer include, for example, rayon, polyester, polyethylene and polypropylene.

Usually, the fluid-permeable layer has basically the same length and width as the overall absorbent structure, or at least the same length and width as the overall absorbent layer. In alternative embodiments, the fluid-permeable layer may have a surface area which is from 35 percent to 350 percent of the area of the absorbent structure, or the absorbent layer.

The fluid-impermeable patch desirably is in the form of a film, and may be produced from any of the aforementioned synthetic and natural materials. In a preferred embodiment the patch is a thermoplastic film produced from a thermoplastic resin. Alternatively, the patch may be in the form of a tightly woven cloth produced from natural or synthetic fibers including synthetic polymer fibers. The film or cloth should be fluid-impermeable, that is, it should not absorb or pass a significant amount of fluid liquid insults and should substantially block the passage of fluid liquid insults.

The area of the fluid-impermeable patch is less than the surface area of the fluid-permeable layer, if present, and the underlying upper surface of the absorbent layer. Desirably, the area of the fluid-impermeable patch is from 2 to 90 percent of the area of the fluid-permeable layer or the absorbent layer, preferably from 5 to 70 percent, more preferably form 10 to 50 percent and still more preferably from 20 to 40 percent.

When incorporated into some common absorbent devices, such as, for example, disposable diapers, incontinent devices or garments and training pants, the length of the fluid-impermeable patch desirably is from 3 cm to 90 cm, preferably from 5 cm to 60 cm, and more preferably from 10 cm to 40 cm. The width desirably is from 1 cm to 25 cm, preferably from 2 cm to 18, and more preferably from 4 cm to 12 cm. The thickness of the fluid-impermeable

patch desirably is from 1 μm to 300 μm, preferably from 5 μm to 200 μm, and more preferably from 10 μm to 75 μm.

In an embodiment wherein the upper surface of the absorbent layer is adjacent to, covered with or in contact with a fluid-permeable layer, the fluid-impermeable patch is present on at least one of the two surfaces of the fluid-permeable layer. It may be positioned on the surface next to the upper surface of the absorbent layer so that the patch is between the fluid-permeable layer and the upper surface of the absorbent layer. Or it may be positioned on the outer surface of the fluid-permeable layer, in which case the fluid-permeable layer is between the patch and the absorbent layer.

In an alternative embodiment the patch may be produced on the target area of an absorbent structure by imprinting or embossing the target area of the existing structure with a plastic or resinous material to render it fluid-impermeable. When produced in this way and used with a fluid-permeable layer, the fluid-impermeable aspect of the patch may be present on both surfaces of the fluid-permeable layer, as well as throughout it. Alternatively, if the structure contains no separately definable fluid-permeable layer, the imprinting or embossing may be done directly upon the absorbent layer.

Generally, the dimensions of the fluid-permeable layer are the same as the overall absorbent structure. Often this is the layer which is in contact with the wearer of a personal care device or garment within which the absorbent structure is incorporated. There is a wide range of suitable thicknesses for the fluid-permeable layer, depending upon the materials of construction and amount of compression within the device or garment. Generally, the thickness of the fluid-permeable layer will range from 0.2 mm to 10 mm.

While some insults may be of a gradual or semi-continuous nature, others which are particularly problematical are those resulting from a rapid physiological discharge of a fluid of biological origin, such as, for example, urination or the hemorrhaging of blood. In this context, fluid-impermeable is defined as absorbing or passing less than 5 percent of a fluid insult within 5 minutes of the onset of the insult. Assuming some motivating force, such as, for example, gravity, hydraulic pressure or hydrostatic pressure, greater than 95 percent of the fluid insult is diverted from the insult point on the fluid-impermeable patch and along the surface of the patch to its edge, where it is directed to the fluid-permeable layer for transmission to the absorbent layer.

With a rapid insult of fluid on the fluid-impermeable patch, the effect of the patch is to spread the flow of the insulting stream over a larger area of the absorbent structure by diverting it to the edges of the patch. Thus, soon after initial contact with the absorbent structure, a relatively large total area of the fluid-permeable layer and the absorbent layer are contacted with the insulting stream. Any given local area of the absorbent layer of the structure is contacted by only part of the impinging stream, and, thus, is less likely to be overwhelmed and saturated than if assaulted directly by the total insult. Even if the insult only

partially impinges upon the fluid-impermeable patch, at least some of the insulting fluid is directed to an area of the fluid-permeable layer and the absorbent layer which otherwise would not be an initial point of contact.

That part of the absorbent layer which is under the patch is not wasted. Fluid which has been diverted by the patch to the edges thereof before coming in contact with the absorbent layer can spread outward toward the extremities of the absorbent structure, and it can also spread inward, under the patch. The overall efficiency of utilization of the absorbent layer and the materials therein is, thus, increased.

The diversionary action of the fluid-impermeable patch, as described above, has the effect of increasing the total area of the fluid-permeable layer and the absorbent layer subject to initial contact with the insulting fluid in comparison to a structure with no patch. Depending upon the motivational force behind the insult this can be very rapid, as would be observed, for example, when saline solution is poured onto a solid surface of some solid material, such as the top of a table. With a larger percentage of the absorbent layer subject to initial insult, and a smaller percentage of the total insulting fluid impinging upon any given area of the absorbent layer, secondary problems in absorbent structures, such as gel blocking and the necessity of transport away from the insult site through, for example, wicking, are considerably reduced. The result is a more efficient use of the absorbent materials in the absorbent layer.

In view of the above described aspects of the absorbent structure of this invention, for use in various absorbent devices and garments, the absorbent structure should be positioned therein so that the fluid-impermeable patch is between the anticipated source of the insult and the absorbent layer of the structure. In addition to varying the general location of the absorbent structure within the device or garment as needed, the size and shape of the fluid-impermeable patch can be varied, as well as the percentage of the area of the upper surface of the absorbent layer which is shielded by the patch. Any suitable shape for the patch may be used, such as, for example, square, rectangular, triangular, round or oval, or a more complex shape comprised of various parts of, or combinations of, the basic shapes. This aspect of the absorbent structure may be varied as needed and as appropriate for the device or garment in which the absorbent structure is used.

When the absorbent structure of this invention is used in an absorbent device or garment, the device or garment may include various other layers or other structural elements in combination with the absorbent structure, such as, for example, those disclosed in U.S. Patents Nos. 5,261,899; 5,258,221; 5,171,236; 5,234,422; 5,098,422; 5,135,522; 4,904,249; 4,834,739; 4,944,735; 5,180,622; 5,264,082; 5,149,335; 5,149,334; 5,124,188 and 5,260,345; 5,268,224; 5,200,248; 5,190,563 and 5,061,259.

MRI of Absorbent Structures

Nuclear magnetic resonance (NMR) spectroscopy is an analytical technique that allows one to obtain a characteristic spectrum of complex components in mixtures. The signal one sees in NMR is proportional to the number of particular atoms in the sample. The most common atom to observe in NMR is hydrogen.

The extension of NMR to medicine is the technique of magnetic resonance imaging (MRI). A typical MRI instrument uses nuclear magnetic resonance to see the hydrogens on water, the most prevalent chemical in the body. With MRI one can obtain a three dimensional map of water in the body. Instruments in use today use "computer aided tomography" (CAT) to view a slice of the body in any of the three orthogonal planes. This concept, based on constructing a real time image of a planar slice focused in the third dimension, remains the same when adapted to the study of absorbent structures. We have used this technique to look at a flowing saline solution in a fiber matrix of an absorbent structure.

This work was done using a Siemens MAGNETOM™ SP/4000 magnetic resonance imager operating at 1 tesla of magnetic flux density and a frequency of 42 MHz to detect protons. The instrument was operated by Regional Imaging Center located in Auburn, Michigan. Various slices of the sample were scanned; the output was a map of signal intensities from the volume elements in the plane of the scan. A monochrome image of the scanned section was visible on a screen to guide experimental efforts.

The resolution of the signal, that is, the dimensions of the volume element, can be modulated by the settings of the instrument. The time required to collect a signal from a particular location is one of these settings, and therefore one must compromise among the speed of data collection, the precision of the map of moisture content, which is related to pixel size, and the size of the region of interest. These signal intensities can be related to the concentrations of water at these various locations by comparison with the signal from liquid water and the baseline signal from air.

For studies of single or multiple insults by aqueous fluids to absorbent structures containing various structural elements, including superabsorbent polymers, any possible signal contribution from the structural elements of the absorbent structure itself can be corrected for or subtracted from the signal after insult. Usually these baseline contributions are very small or negligible. This versatility in handling the collected data can be used to study the effect of multiple insults on an absorbent structure. For example, after an absorbent structure has become relatively stable following one or more initial insults, a subsequent insult to the structure may be observed. The distribution of the additional moisture content from the subsequent insult along with any redistribution of the moisture content due to the initial insult can be determined by subtracting the signal observed prior to the subsequent insult from the signal observed after the subsequent insult.

For each run in these experiments 11 files of 128 x 128 pixels and 32 files of 256 x 256 pixels were stored, as well as numerous values specifying the conditions of the scans. Each pad configuration generated over 6 megabytes of data. Following the generation and storage of this data, the method involves using means for data transfer, means for decoding, and means for visualization and display.

In order to fix the specimens in the MRI unit a holding device was machined from cast polymethyl-methacrylate, a transparent plastic. Plastic was necessary because most other materials would either absorb radiation or be affected by the intense magnetic field. By relying on gravity the maximum load that could be applied to the sample was the 1.8 kPa (0.25 psi) due to the weight of the solid plastic block. The dimensions of the coil limited the size of the holding assembly, and denser solid materials, such as metals, could not be used. Higher loads can be applied to the absorbent structure by mechanical means, such as hydraulic pressure.

FIG. 1 is a schematic of the experimental layout. The holding device is shown with the plastic block 12 over the absorbent structure 11, also referred to herein as a pad. The insult to the absorbent structure is introduced through a flexible plastic tube 13. For the experiment, an absorbent structure was fitted into this holding device and the entire assembly was set into the head coil 14 of the MRI instrument. The head coil 14 is surrounded by the magnet 15.

The specimen was aligned with two laser beams indicating the center of the magnetic field. The fluid insult was introduced into the sample by a hand-operated syringe connected by a flexible plastic tube to the vertical delivery tube machined from the plastic block. In these runs, 25 mL of fluid was delivered in 1-2 seconds. The fluid supply and syringe operator were positioned approximately 5 meters (15 ft) from the sample to avoid the strong magnetic field around the detector. The long flexible plastic delivery tube which connected the syringe to the sample was filled with fluid before the experiments were begun. The fluid used was 0.9 weight percent aqueous NaCl solution.

In some pads (absorbent structures) a fluid-impermeable patch was placed in the middle of the top surface immediately under the tissue layer. In other pads the patch was omitted. The pad was covered with liner material just before testing. The method of this invention, as used in this study, is useful in determining the effect of structural elements, such as, for example, the fluid-impermeable patch on the flow pattern and ultimate distribution of the fluid insult upon the absorbent structure.

The insult was monitored with one-second scans of the center section of the sample made at one-second intervals. The scanned section was approximately 1 cm thick. FIG. 2 shows the first plane scanned, which is termed the "transverse" plane 22. Thus, a transverse scan is a scan in the transverse plane. FIG. 2 shows the plastic block 12, the absorbent structure 11 and the wetted region 21 of the absorbent structure 11, the wetting due to the insult.

After ten scans at a total elapsed time from the time of the insult of 20 seconds, no further rapid change in the images was observable. A scan in the "coronal" plane 23, known as a coronal scan, was then done. FIG. 2 shows a view of a coronal plane 23 below the plane of the absorbent structure 11 for clarity of illustration. Of course, the actual coronal scan was performed in the coronal plane which contains the absorbent structure 11.

For the coronal scan the thickness of the scanned planar region was intentionally set to include the entire pad. This integrated signal intensity reflects the total relative moisture content through the thickness of the pad.

The coronal scan was followed with 32 high resolution transverse scans "stepping" through the sample from back to front with slices of less than a centimeter in thickness. These are similar to the initial high speed transverse scans of the center slice, but the resolution in the two scanned dimensions is much better because the scan time is longer.

The images observed on the screen during the experiments, which are maps of the intensity obtained from each of the three scanning protocols, provide only gross information. Nevertheless, individual layers of fluff can be observed in high resolution scans with scan times of 16 seconds. The rapid scans of 1 second yield an image that is lower in contrast and more diffuse.

While gross information can be gained from the screen images, precise quantification requires numerical values for the signal strengths at each location. The collected data for the signal strength at each location were transferred to a data file of a VAX™ computer (Trademark of Digital Equipment Corporation, DEC) with the cooperation of both the Siemens Company and Digital Equipment Corporation. It was then possible to manipulate the signal values for each pixel for each scan of each run with computer programs for analysis and visualization of the data that allowed precise comparisons of moisture contents.

FIG. 3A is a typical contour plot of the coronal image. The contours represent various relative moisture contents accumulated through the whole thickness at each position across the span after 24 mL of 0.9 weight percent saline solution has been introduced into the center. A different representation of the same data can be seen in a surface plot as shown in FIG. 3B. The data for FIG. 3A and FIG. 3B are the same, that is, the signal strength is summed over the whole thickness as a function of the two "flat" dimensions of the sample.

Integration of the relative moisture values over the whole extent of the pad should be the equivalent of the 25 mL of the insult. FIG. 4 shows a plot of the total signal from these coronal images after each insult for a particular series of experiments, one of which is shown with circles, the other with boxes. Deviations from zero intercept are due to inconsistent filling and draining of portions of the fluid delivery line. An improvement of the apparatus would include positive shutoff of flow after the insult to prevent this problem.

FIG. 5A shows a view of a typical monochrome image as it would be viewed on the screen of a high speed scan of a transverse slice showing fluid coming into the absorbent

structure 11, here represented by the dashed outline, from the top. The top of FIG. 5A corresponds to the upper part of the plastic block. FIG. 5B is a surface plot of the relative signal intensity inside the solid outline of FIG. 5A. The arrow 51 in FIG. 5B indicates a viewing angle of this surface. FIG. 5C is the profile of maxima of moisture content as viewed from arrow 51 and oriented as in reality with the top of the image corresponding to the upper part of the plastic block. The large spike near the bottom of the profile corresponds to the wetness of the upper surface of the absorbent structure at the instant an image is taken. In this particular image taken at the initial moment of insult, the fluid is moving down the delivery tube and wetting the top surface of the pad before penetrating it. The peaks above the large spike are the result of this fluid in the delivery tube.

FIG.s 6A, 6B and 6C show a series of similar profile plots showing the maximum moisture content viewed across the center line of the absorbent structure for every two seconds during three fluid insults. Keeping in mind that the insult is administered by a hand operated syringe at a distance of 5 meters, the scans at 0 and 2 seconds in FIG. 6A are basically the same flat baseline. The scan at 4 seconds shows some fluid near the top, and the scan at 6 seconds corresponds to the major portion of the insult flowing through the flexible tube and arriving at the upper surface of the absorbent structure. Little fluid movement occurs after the driving pressure of the hand operated syringe stops.

In the FIG. 6B series of scans, the profile view of the baseline scan at 0 seconds shows a large broad peak near the bottom which corresponds to the absorbed fluid from the first insult. Similarly, the large broad peak near the bottom of the baseline scan at 0 seconds of FIG. 6C corresponds to the absorbed fluid from the first and second insults.

Another indication of the relatively small amount of capillary flow, that is, wicking, is the sharp gradient seen in the surface plots from the coronal views. In FIG.s 7A, FIG. 7B and FIG. 7C are presented three surface plots from three successive insults on the same scale. Note the flat tops all coming to the same height. This represents saturation, and subsequent insults simply make the saturated region bigger. In general, we have either saturated plateau or unsaturated plains regions; there is not much intermediate "damp" area.

To demonstrate the effect of a deflector region, that is, a fluid-impermeable patch placed near the target area of an absorbent structure, the profiles of relative moisture content at a series of positions for two different absorbent structures, one with a fluid-impermeable patch and one without a fluid-impermeable patch, were compared. FIG.s 8A-8F illustrate the distribution of three 25 mL insults of saline solution in pads with and without a fluid-impermeable patch. These curves represent vertical sections through surface plots similar to those in FIG.s 7A-C.

Without a patch, FIG. 8A, the fluid was distributed over a radially symmetrical area approximately 5 cm (2 inches) in diameter; the average fluid concentration in this region is approximately 450 units, corresponding essentially to saturation. With a 5 cm (2 x 2 inch) patch,

FIG. 8D, the same amount of fluid is distributed over a toroidally-shaped region approximately 7.5 cm (3 inches) in diameter with a 2.5 cm (one inch) diameter drier region in the middle. The average fluid concentration in the ring of wetness was only about 150 units with peaks around 300 units.

The effects of two additional insults on each pad, up to a total of 75 mL in each, are shown in subsequent plots, FIG. 8B and FIG. 8C without the patch, and FIG. 8E and FIG. 8F with the patch. Even after three insults to the absorbent structures, which simulate diapers, the sample with the patch does not have such a well developed "plateau" of saturation as indicated for the control. This quantifies what a user of a diaper containing such an absorbent structure would experience as a drier, more comfortable feel. Using a deflector region allows utilization of more of the core, and, hence, improves efficiency.

Examination of the test samples showed the diaper pad without the patch to be wet on both its surfaces and the pad with the patch to have the fluid more uniformly distributed and much less wet on its surfaces. Both of these absorbent structures were constructed with a polypropylene nonwoven on the upper surface, which was insulted. An additional example utilizing no nonwoven material but with the patch showed intermediate performance.

The deflector patch led to more efficient distribution of the fluid over a larger portion of the pad. Modification of this configuration with respect to shape, relative size, placement, and permeability can be envisioned.

This technique showed the surprising result of how little natural wicking occurred in these experiments. By directly observing the fluid in real time the question of whether the analysis technique affects the result, as would be the case with cutting and weighing, can be eliminated. Of course wicking occurs under some conditions, such as higher loads which compress the pads to a greater extent creating smaller diameter capillaries with higher capillary pressures.

Another major interest is what is the effect of superabsorbents and further, the effect of differences in superabsorbents. Ascertaining the correlation of superabsorbent properties with fluid distribution has in the past been very difficult. This technique simplifies this correlation.

This technique provides a map of water concentration in three dimensional space as a function of time.

Examples of the Absorbent structure

Absorbent structures consisting of composite pads prepared by standard techniques were used to simulate the central portion of a larger absorbent structure, such as that typically found in a diaper. Cellulose fluff was disintegrated with compressed air and layered onto tissue forming 35.6 x 35.6 cm (14 x 14 inch) pads, which were then covered with tissue and then pressed to 1.25 cm (1/2 inch) thickness. Four 15 x 15 cm (6 x 6 inch) samples

weighing 28 to 31 grams were cut from the larger pads and stored at 1.25 cm (1/2 inch) thickness in a constant temperature and humidity room at 21°C (70°F), 50 percent relative humidity, until used.

In some pads a fluid-impermeable patch was placed in the middle of the top surface immediately under the tissue layer right after the compression step. In other pads the patch was omitted.

A pad was fitted into a holding device and the entire assembly was set into the head coil of a Siemens MAGNETOM SP/4000 magnetic resonance imager (operating at 1 tesla, 42 MHz proton), commonly used for medical diagnosis, so that magnetic resonance imaging (MRI) could be performed on the absorbent structure. This instrument allows the determination of the signal strength at any location within the sample. This signal can be used to determine the concentration of water at these various locations by comparison with the signal from liquid water and the baseline signal from air. The output from the instrument is a map of the signal intensities from a set of volume elements distributed throughout the selected sets of the three dimensions of the sample pad. The resolution of the signal, that is, the dimensions of the volume element can be modulated by the settings of the instrument. The time required to collect a signal from a particular location is one of these settings, and therefore one must compromise among the speed of data collection, the size of the sample, and the precision of the map of moisture content.

Fluid was introduced into the sample by a hand-operated syringe connected by a flexible plastic tube to the vertical delivery tube machined from the plastic block. The desired amount of fluid was drawn into the syringe through a Y-shaped connection with one side open and the other closed; for delivery the other was opened and the first side closed. Generally, 25 mL of fluid was delivered in 1-2 seconds. The fluid supply and syringe operator were positioned approximately 5 meters (15 ft) from the sample to avoid the strong magnetic field around the detector. The long flexible plastic delivery tube which connected the syringe to the sample was filled with fluid before the experiments were begun. The fluid used was an aqueous solution which contained 0.9 percent weight percent NaCl.

FIG. 3A is a contour plot of an absorbent structure 15 x 15 cm x 1.25cm (6 x 6 x 1/2 inch) obtained by magnetic resonance imaging. The contours represent various relative moisture contents accumulated through the whole thickness at each position across the span after 25 mL of 0.9 weight percent saline solution has been introduced into the center. The view of FIG. 3A is down the delivery axis upon which the fluid insult has been delivered to the target area of the surface of the absorbent structure. FIG. 3A shows that the maximum relative moisture content is located at the center of the insult point, which appears to be saturated. Moving across the structure outward from the center of the insult point, we then find successive contours representing progressively less relative moisture content as the distance

from the insult point is increased. This is precisely what would be expected from a rapid insult of fluid.

FIG. 8A shows profiles of relative moisture content at various positions along one side of a 15 x 15 cm x 1.25cm (6 x 6 x 1/2 inch) absorbent structure which has no patch. The horizontal axis represents distance in cm from the point of insult at 0. The vertical axis is arbitrary numerical units directly proportional to moisture. FIG. 8A shows a relatively high moisture content in the immediate area surrounding the insult site which then falls off with increasing distance from the insult site.

These results show that MRI is an effective analytical tool for the measurement of aqueous fluid distribution within an absorbent structure. When an absorbent structure in scanned repeatedly after a fluid insult at scan times which are short relative to the flow and ultimate disposition of the fluid insult, the movement over time of the fluid insult can be followed. This information can be used as the basis for inferences related to the various distribution mechanisms at work within the absorbent structure after insult by a fluid.

FIG. 8D shows the same view as FIG. 8A, but for an absorbent structure of this invention, which has a centrally located fluid-impermeable patch.

These FIG.s illustrate the distribution of 25 mL of 0.9 weight percent saline solution, with and without a fluid-impermeable patch. Without a patch, the fluid was distributed over a radially symmetrical area approximately 5 cm in diameter; the average fluid concentration in this region is approximately 450 units. With a 5 x 5 cm (2 x 2 inch) patch, the same amount of fluid is distributed over a toroidally-shaped region approximately 7 cm in diameter with a 2.5 cm diameter relatively dry region in the middle; the average fluid concentration in the ring of wetness was only about 150 units with peaks around 300 units.

The effect of two additional insults on each absorbent structure, up to a total of 75 mL in each, were also studied with this MRI method. Even after three insults to the absorbent structures, the sample with the patch does not have a "plateau" of saturation as extensive (around 450 units) as indicated for the control. This quantifies what a user of such a diaper would experience as a drier, more comfortable feel.

Examination of the final samples showed the absorbent structure without the patch to be wet on both its surfaces and that with the patch to have the fluid more uniformly distributed and much less wet on its surfaces. Both of these simulated diapers were constructed with a polypropylene nonwoven on the top (insulted) surface. An additional example utilizing no nonwoven material but with the patch showed intermediate performance. It is known that the nonwoven material is useful when compared to simple fluff. Therefore, we can conclude that the patch is of greater value than this liner, but the best performance was shown when both the liner and the patch were used.

WHAT IS CLAIMED IS:

1. An absorbent structure comprising:

(A) an absorbent layer having dimensions of length, width and thickness, the absorbent layer having at least an upper surface with dimensions of length and width, wherein the ratio of length to thickness is from 1 to 1000 and the ratio of width to thickness is from 1 to 500; and

(B) a fluid-impermeable patch centrally located adjacent to or covering a part of the upper surface of the absorbent layer, the patch having dimensions of length, width and thickness, the area of the patch being from 2 to 90 percent of the area of the upper surface of the absorbent layer.

2. The absorbent structure of Claim 1 wherein the length of the absorbent layer is from 5 cm to 100 cm, the width of the absorbent layer is from 2 cm to 30 cm and the thickness of the absorbent layer is from 0.1 cm to 5 cm.

3. The absorbent structure of Claim 1 wherein the length of the fluid-impermeable patch is from 3 cm to 90 cm, the width of the fluid-impermeable patch is from 1 cm to 25 cm and the thickness of the fluid-impermeable patch is from 1 µm to 300 µm.

4. The absorbent structure of Claim 1 wherein the absorbent layer comprises one or more of fluff, superabsorbent polymer, cellulosic materials, modified cellulose, cellulose tissue, meltblown synthetic fibers, polyethylene, polypropylene, polyester, polyamide, copolymer of polyester or polyamide, open cell foam, and bicomponent fiber.

5. The absorbent structure of Claim 1 wherein the fluid-impermeable patch comprises one or more of airlaid or meltblown synthetic fibers including rayon, polyester, polyethylene and polypropylene, natural fibers including cotton and cellulose, a thermoplastic film or resin, tightly woven cloth and latex adhesive.

6. The absorbent structure of Claim 1 wherein the fluid-impermeable patch is produced by imprinting or embossing the absorbent structure with a plastic or resinous material.

7. The absorbent structure of Claim 1 wherein the fluid-impermeable patch absorbs or passes less than 5 percent of a fluid insult within 5 minutes of the onset of the insult.

8. An absorbent structure comprising:

(A) an absorbent layer having dimensions of length, width and thickness, the absorbent layer having at least an upper surface with dimensions of length and width, wherein the ratio of length to thickness is from 1 to 1000 and the ratio of width to thickness is from 1 to 500;

(B) a fluid-permeable layer adjacent to the upper surface of the absorbent layer; and

(C) a fluid-impermeable patch centrally located on a part of at least one surface of the fluid-permeable layer and having dimensions of length,

width and thickness, the area of the patch being from 2 to 90 percent of the area of the upper surface of the absorbent layer.

9. The absorbent structure of Claim 8 wherein the length of the absorbent layer is from 5 cm to 100 cm, the width of the absorbent layer is from 2 cm to 30 cm and the thickness of the absorbent layer is from 0.1 cm to 5 cm.

10. The absorbent structure of Claim 8 wherein the length of the fluid-impermeable patch is from 3 cm to 90 cm, the width of the fluid-impermeable patch is from 1 cm to 25 cm and the thickness of the fluid-impermeable patch is from 1 µm to 300 µm.

11. The absorbent structure of Claim 8 wherein the absorbent layer comprises one or more of fluff, superabsorbent polymer, cellulosic materials, modified cellulose, cellulose tissue, meltblown synthetic fibers, polyethylene, polypropylene, polyester, polyamide, copolymer of polyester or polyamide, open cell foam, and bicomponent fiber.

12. The absorbent structure of Claim 8 wherein the fluid-permeable layer comprises one or more of airlaid or meltblown synthetic fibers including rayon, polyester, polyethylene and polypropylene, and natural fibers including cotton and cellulose.

13. The absorbent structure of Claim 8 wherein the fluid-impermeable patch comprises one or more of airlaid or meltblown synthetic fibers including rayon, polyester, polyethylene and polypropylene, natural fibers including cotton and cellulose, a thermoplastic film or resin, tightly woven cloth and latex adhesive.

14. The absorbent structure of Claim 8 wherein the fluid-impermeable patch is produced by imprinting or embossing the absorbent structure with a plastic or resinous material.

15. The absorbent structure of Claim 8 wherein the fluid-impermeable patch absorbs or passes less than 5 percent of a fluid insult within 5 minutes of the onset of the insult.

16. A method for determining the location of aqueous fluid within an absorbent structure with the use of magnetic resonance imaging comprising the steps of:

(A) performing a magnetic resonance imaging scan on the absorbent structure;

(B) collecting and storing data from the magnetic resonance imaging scan;

(C) visually displaying the data.

17. The method of Claim 16 wherein steps (A) and (B) are performed two or more times so that fluid flow with the absorbent structure may be observed.

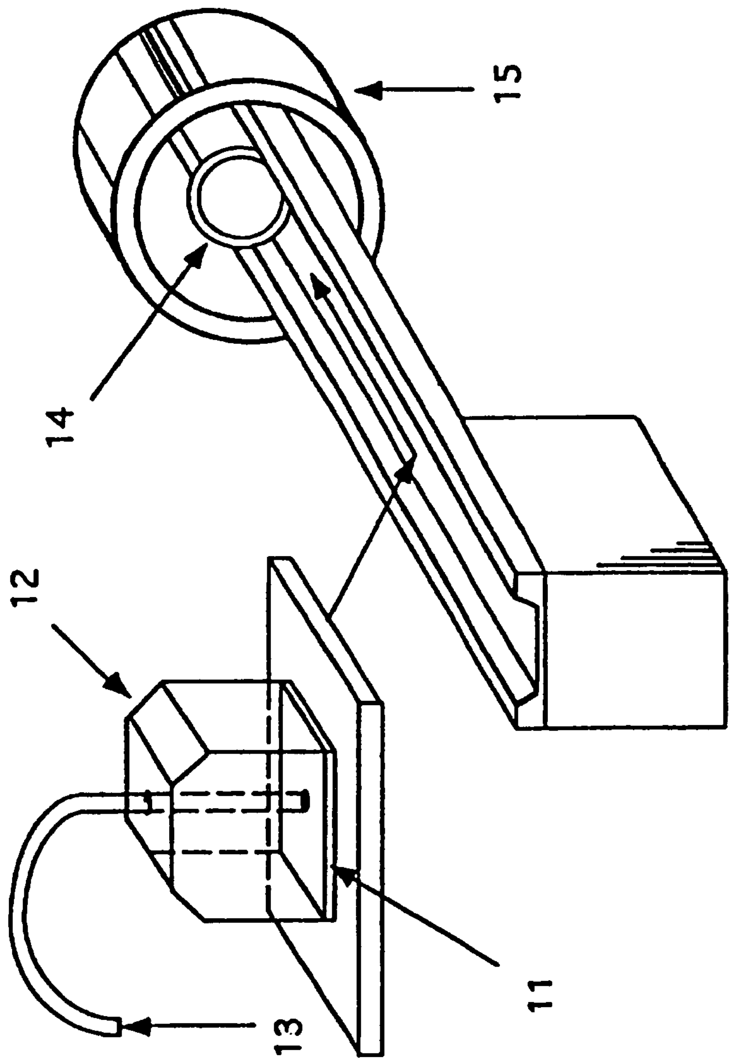


FIG. 1

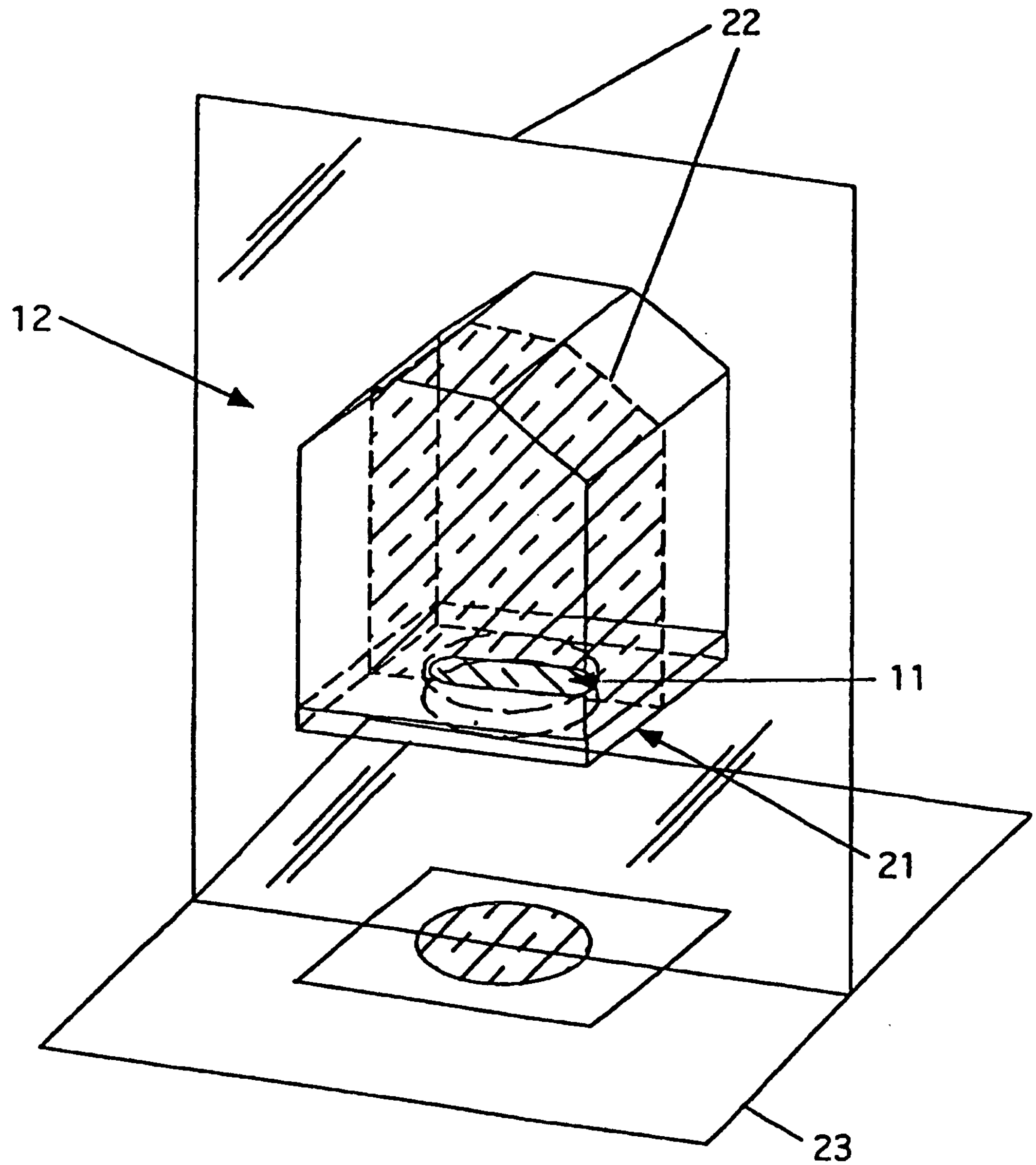


FIG. 2

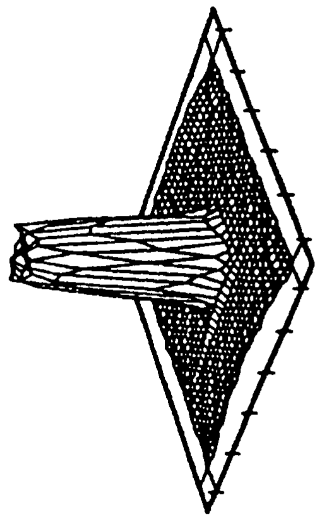


FIG. 3B

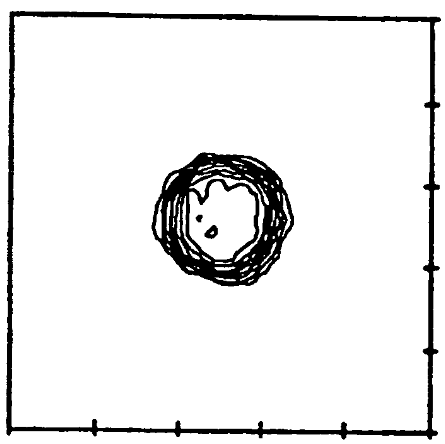


FIG. 3A

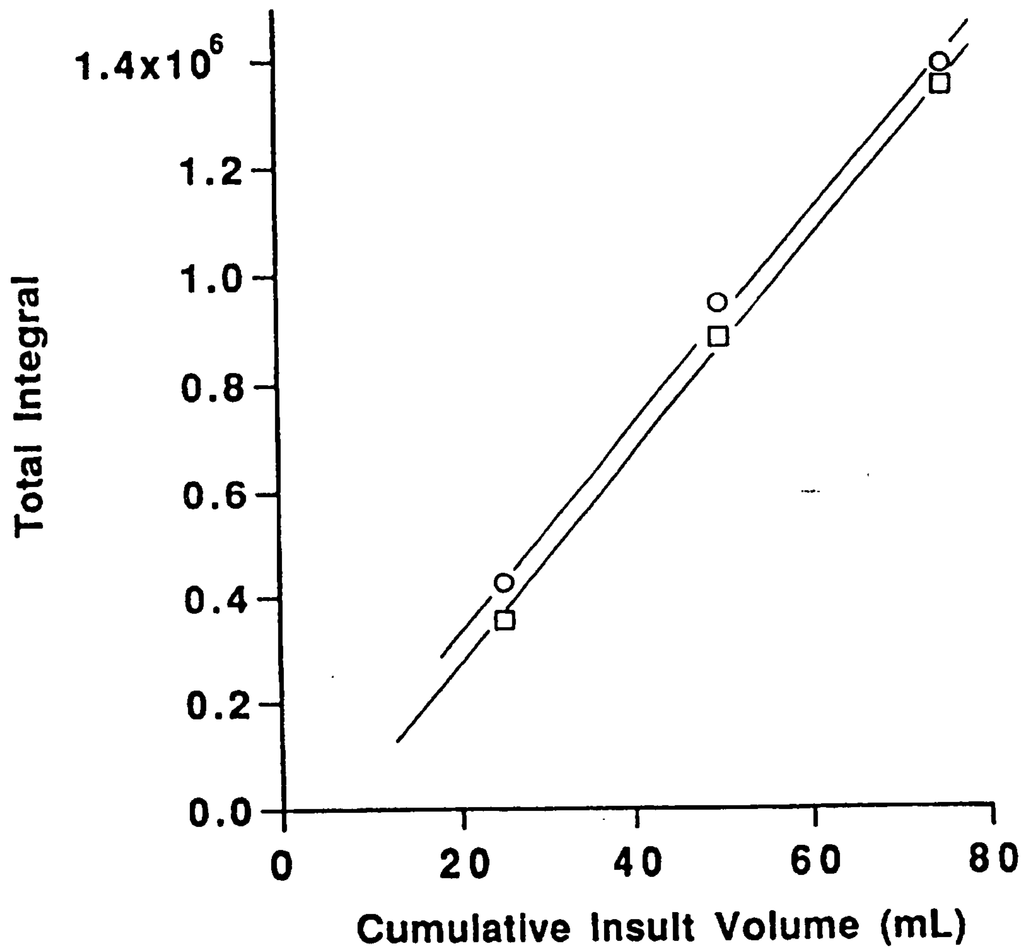

Total Integral
1.4x10^6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
Cumulative Insult Volume (mL)

FIG. 4

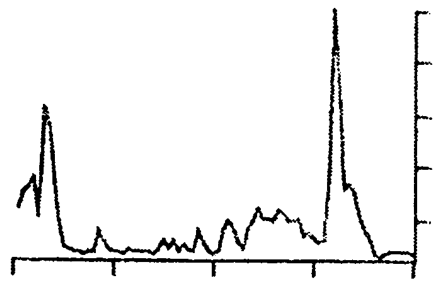


Fig. 5C

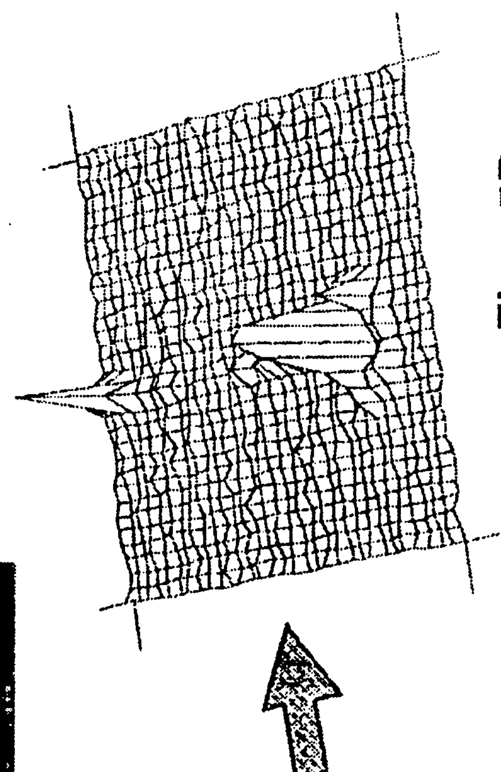


Fig. 5B

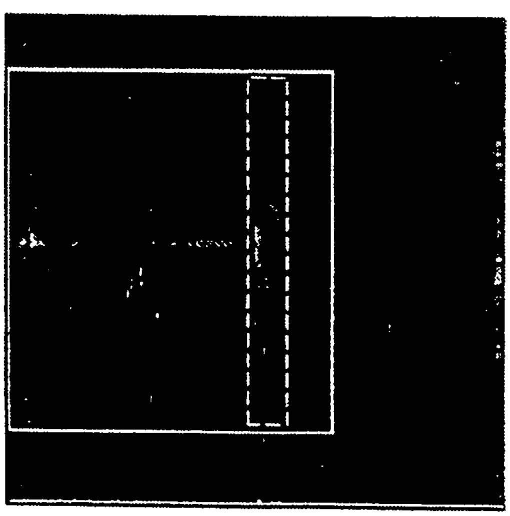


Fig. 5A

FIG. 6A

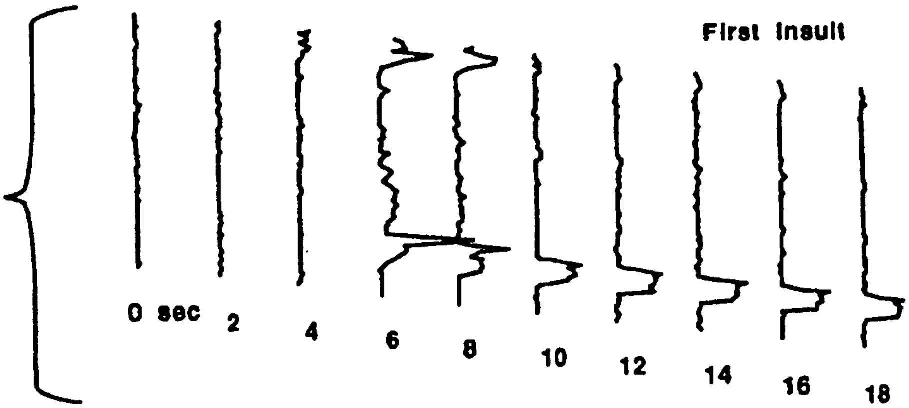


FIG. 6B

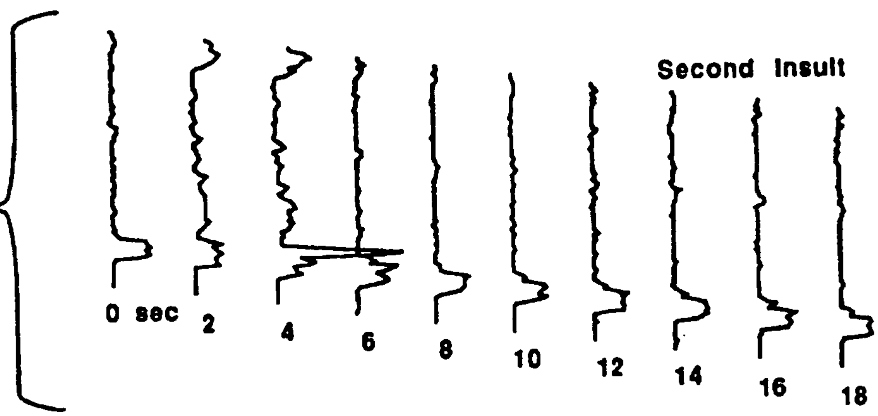


FIG. 6C

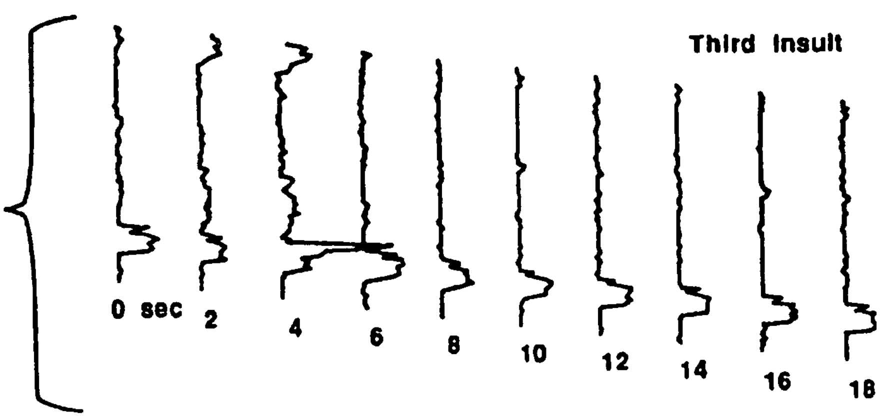
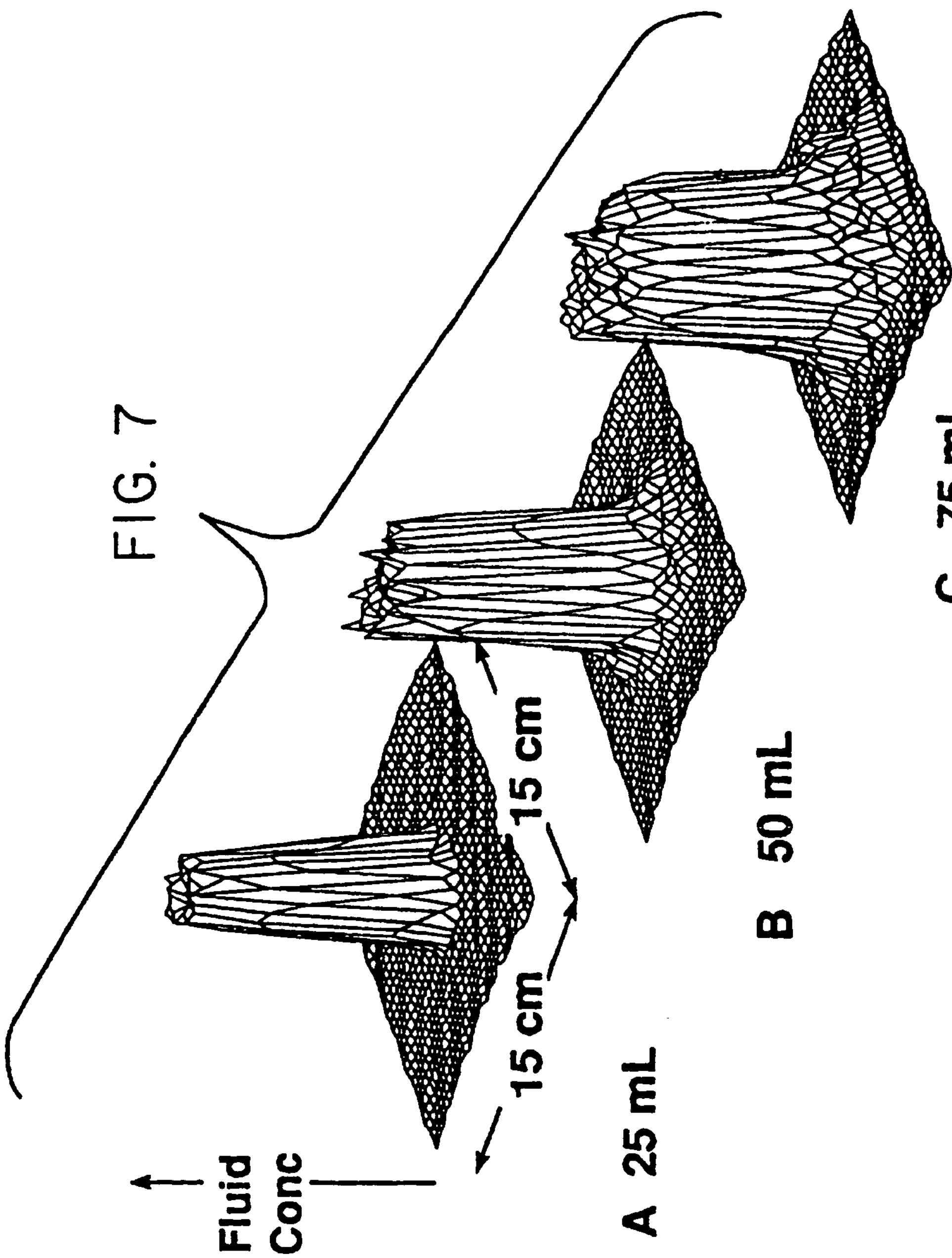


FIG. 7



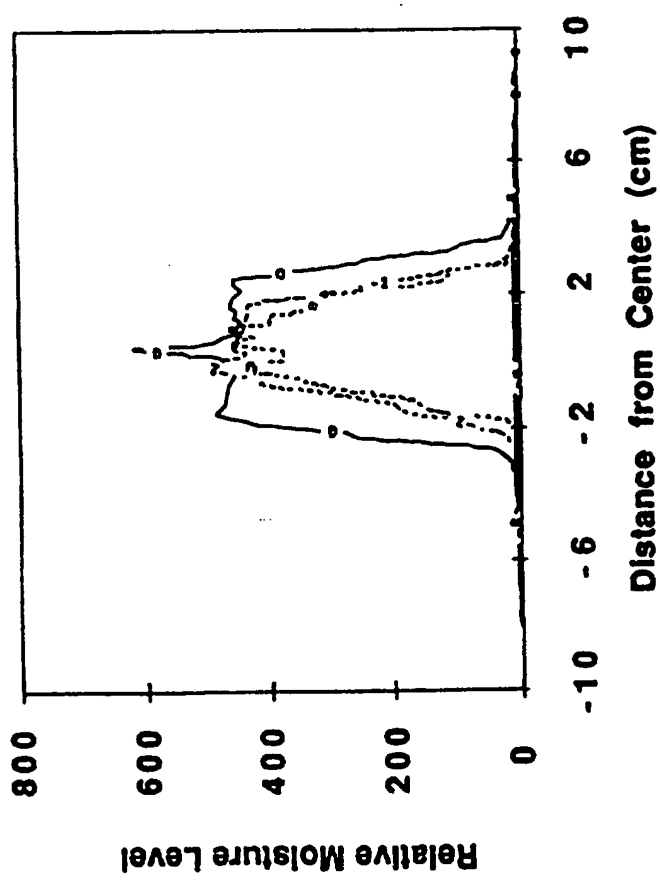

Relative Moisture Level
800
600
400
200
0
-10
-6
-2
2
6
10
Distance from Center (cm)

FIG. 8A

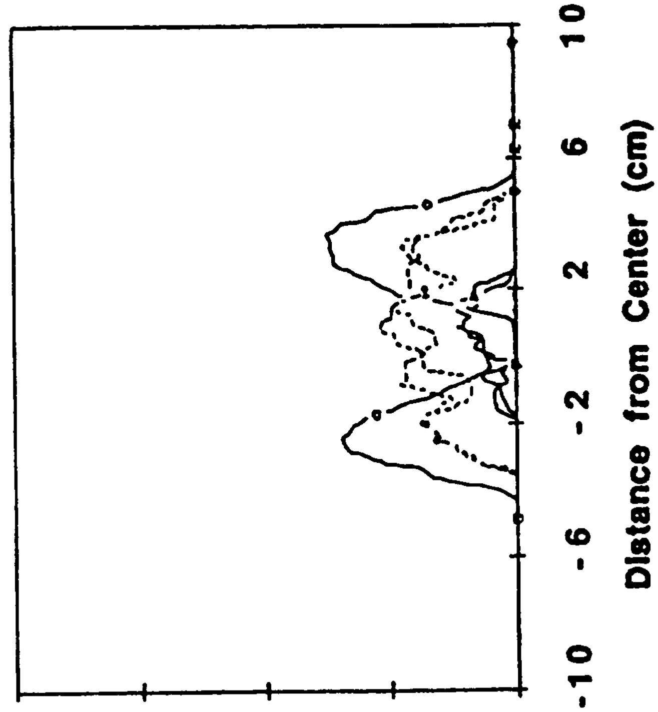

-10
-6
-2
2
6
10
Distance from Center (cm)

FIG. 8D

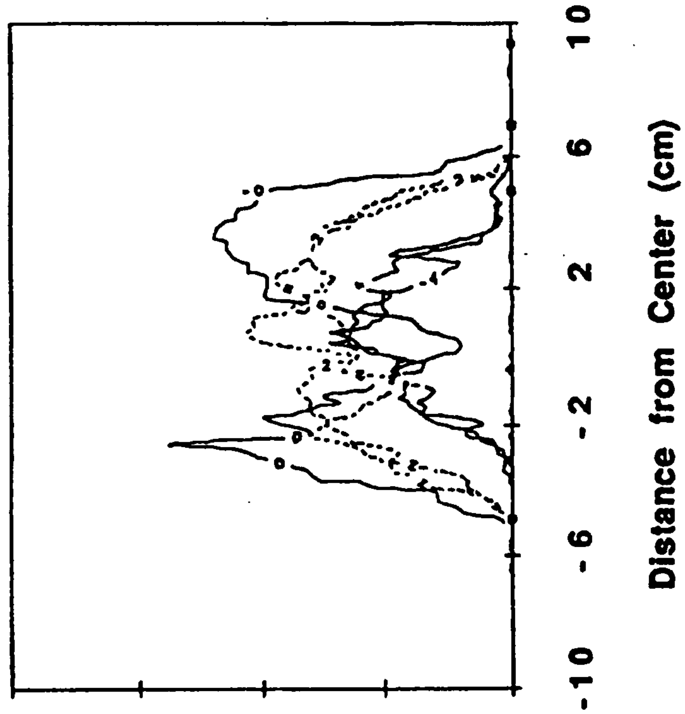
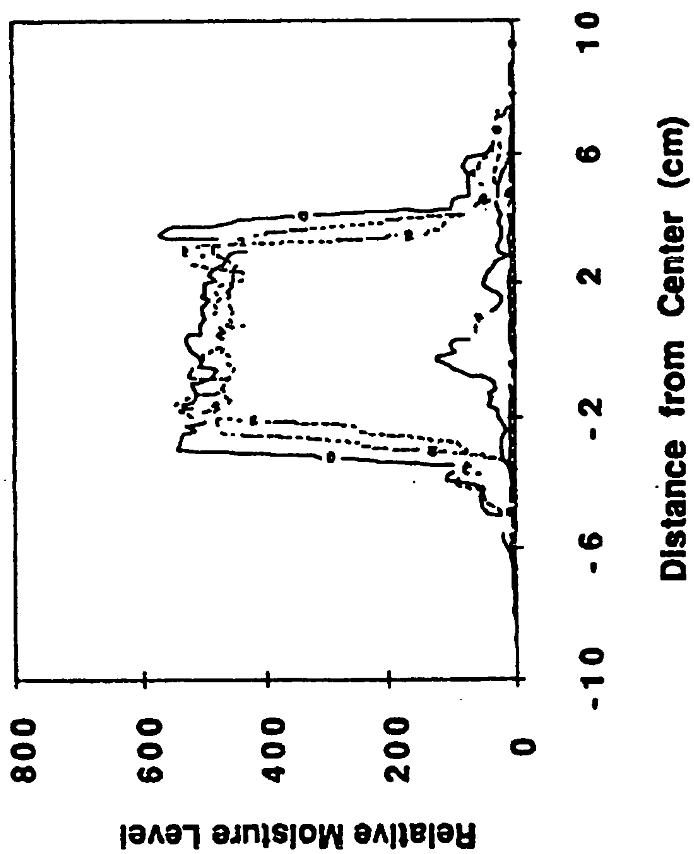

-10
-6
-2
2
6
10
Distance from Center (cm)

FIG. 8E


Relative Moisture Level
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600
400
200
0
-10
-6
-2
2
6
10
Distance from Center (cm)

FIG. 8B

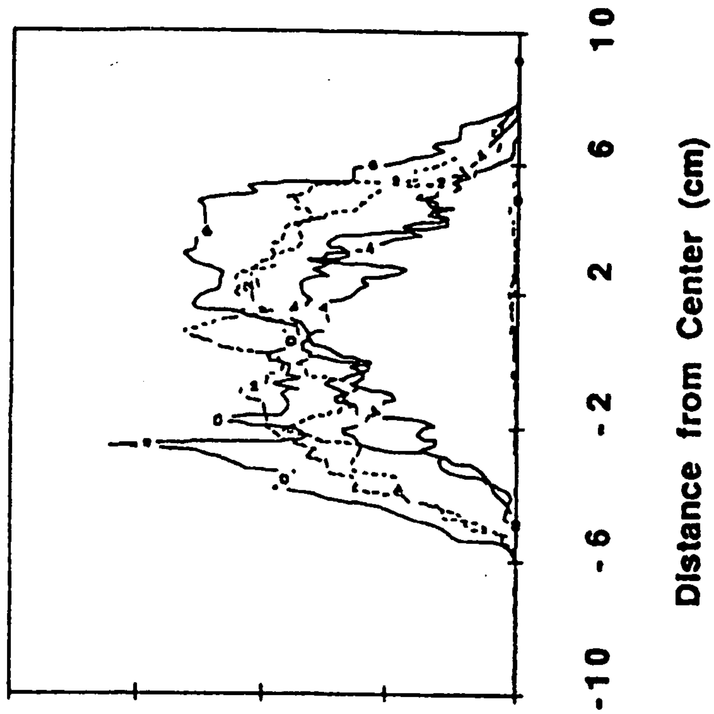
Distance from Center (cm)
-10
-6
-2
2
6
10

FIG. 8F

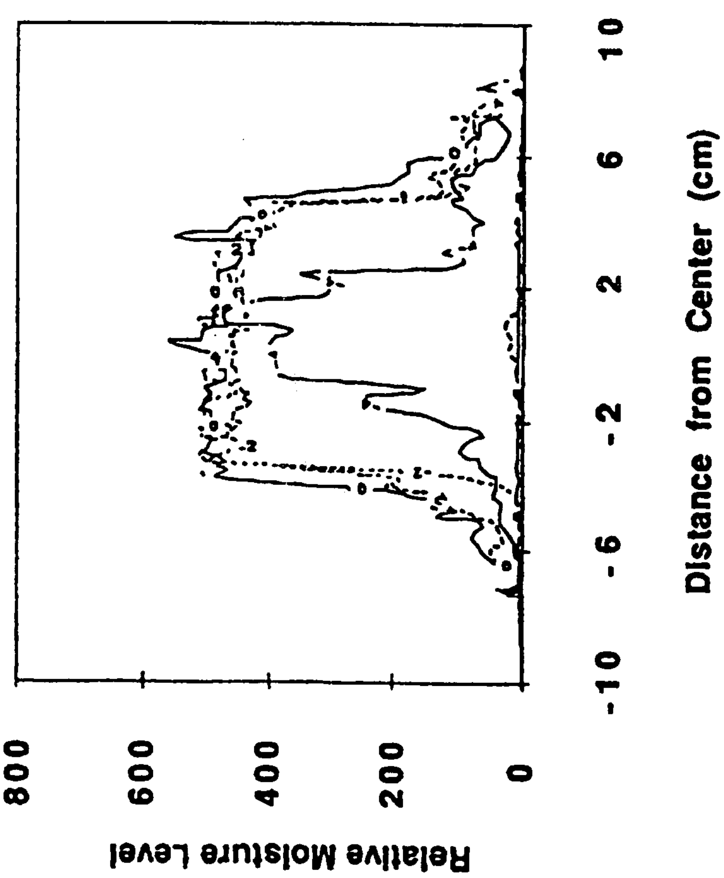
Relative Moisture Level
800
600
400
200
0
Distance from Center (cm)
-10
-6
-2
2
6
10

FIG. 8C